(12) UK Patent Application (19) GB (11) 2 126 388 A

(21) Application No 8322213
(22) Date of filing 18 Aug 1983
(30) Priority data
(31) 410485
410547
(32) 23 Aug 1982
23 Aug 1982
(33) United States of America (US)
(43) Application published 21 Mar 1984
(51) INT CL^3 G06F 3/023
(52) Domestic classification
G4H 13D 14A 14D KU
H1N 446 449 450 454 457 61X 628 744 747 74X HN
U1S 1175 2125 2284 2285 G4N H1N
(56) Documents cited
GB A 2048531
GB 1552753
EP A1 0033910
(58) Field of search
G4H
H1N
(71) Applicants
RCA Corporation,
(USA-Delaware),
30 Rockefeller Plaza,
City and State of New York 10020,
United States of America.
(72) Inventors
Charles Martin Wine,
Nils Olov Ny.
(74) Agent and/or Address for Service
Richard W. Pratt,
RCA International Limited,
Norfolk House,
31 St. James's Square,
London SW1Y 4JR.

(54) Touch responsive apparatus

(57) The apparatus is useful in e.g. electronic games or in a computer-user interface. An example has a touch-plate (30), on which is a two dimensional array of valid touch areas (31-39), supported at its corners by switches (41-44). Different combinations of switches are actuated depending on which area is touched. A decoder (50) produces an indication of the area touched. A two dimensional (5×5) array is described using switches which have two actuated conditions respectively responsive to two forces. A one dimensional array is also described.

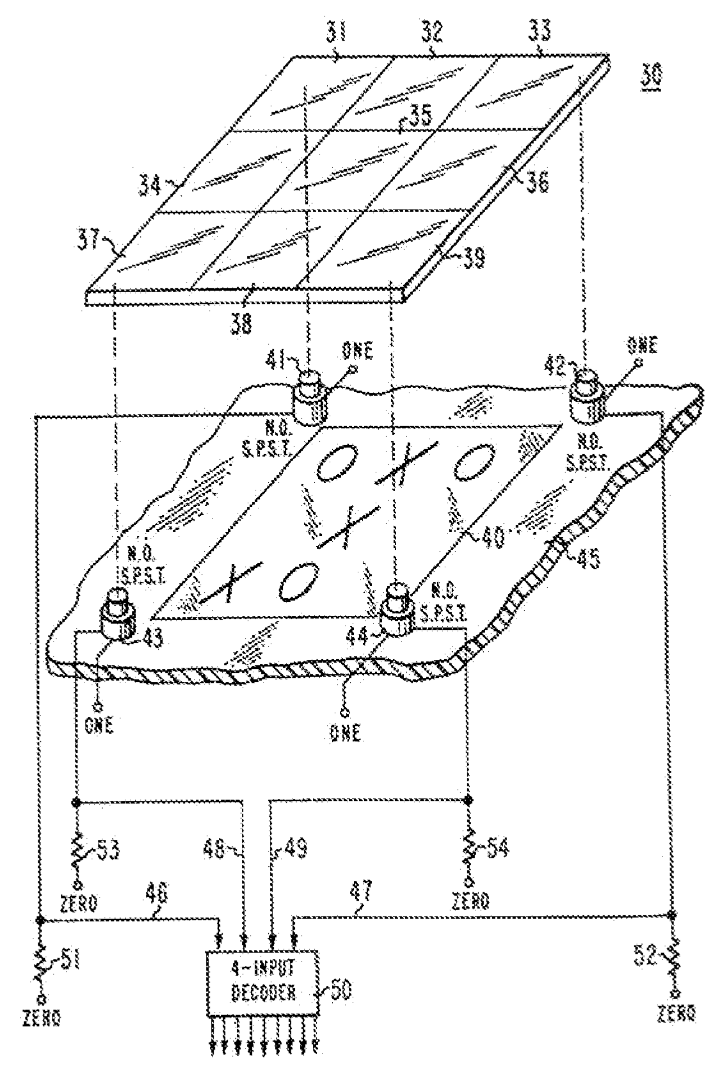


Fig. 3

GB 2 126 388 A

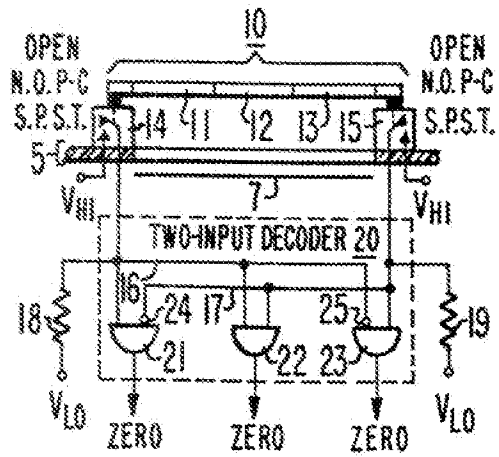


Fig. 1a

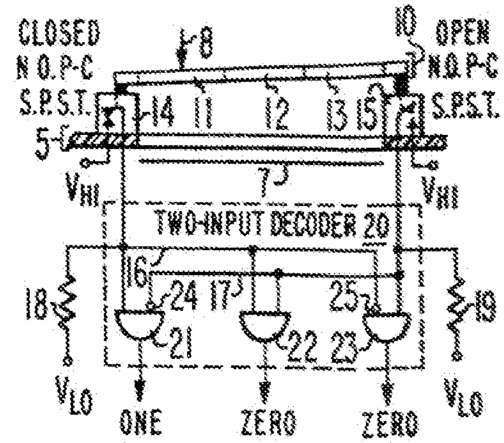


Fig. 1b

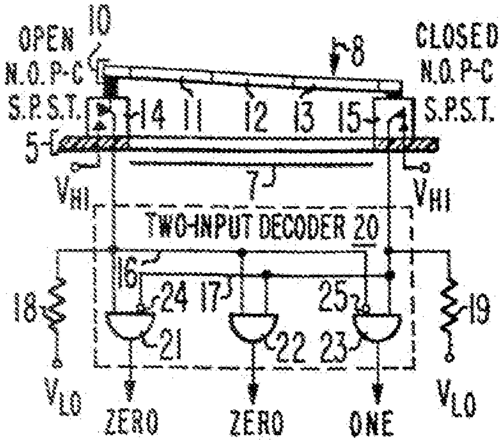


Fig. 1c

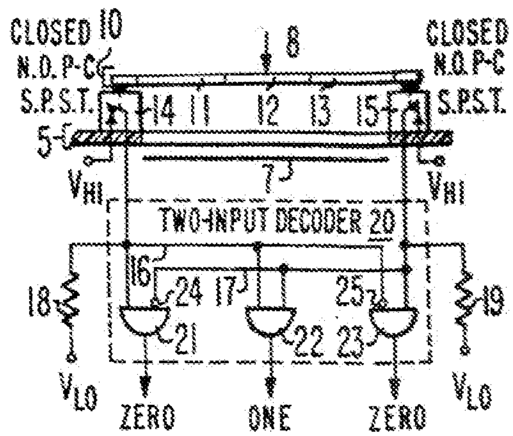


Fig. 1d

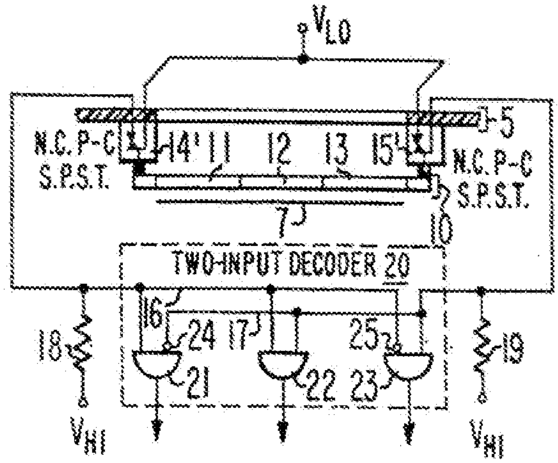


Fig. 2

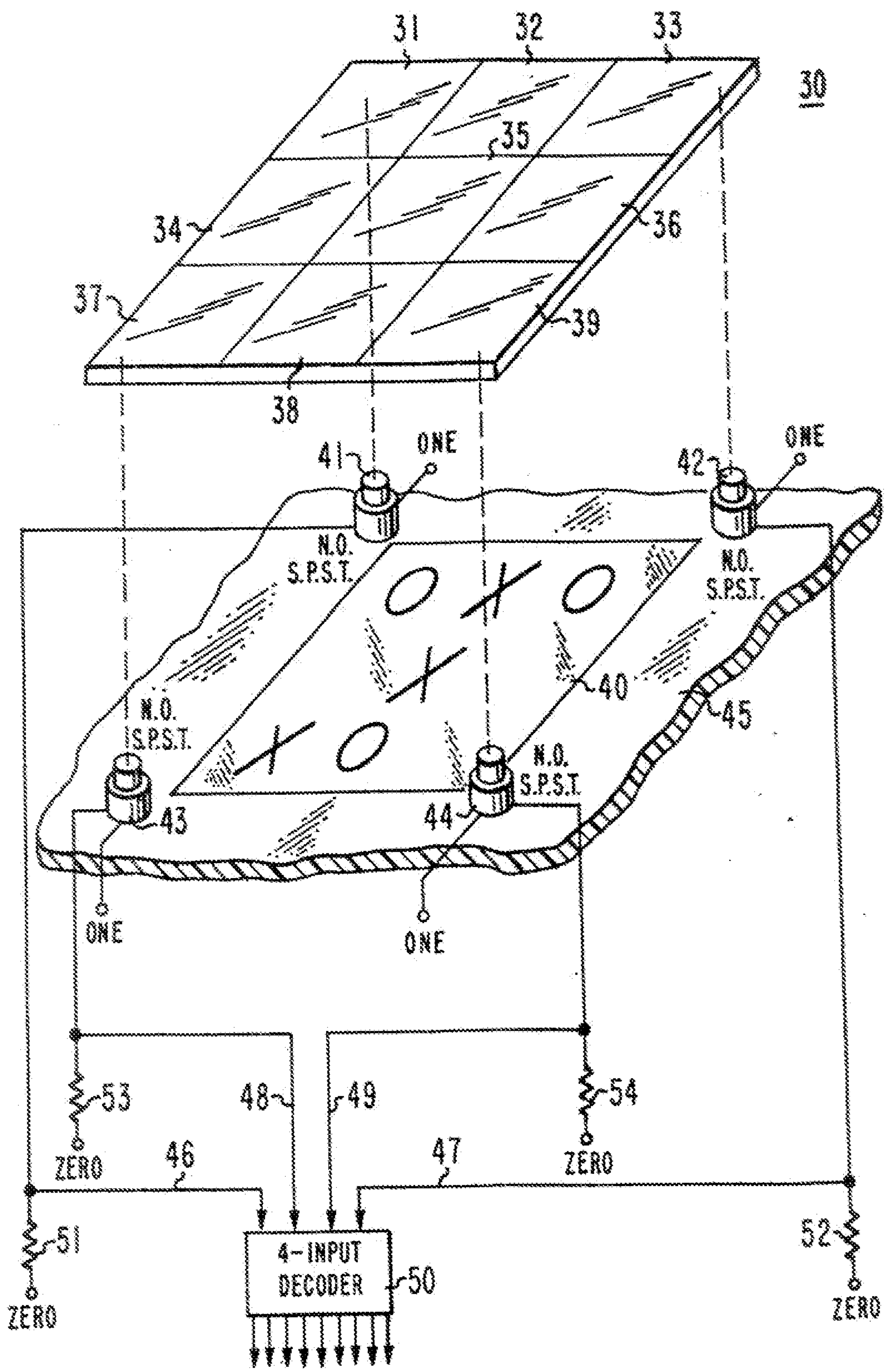

31
32
33
30
35
34
36
37
39
38
41
ONE
42
ONE
N.O. S.P.S.T.
N.O. S.P.S.T.
40
45
N.O. S.P.S.T.
N.O. S.P.S.T.
43
44
ONE
ONE
53
48
49
54
ZERO
ZERO
46
47
51
ZERO
4-INPUT DECODER
50
52
ZERO

Fig. 3

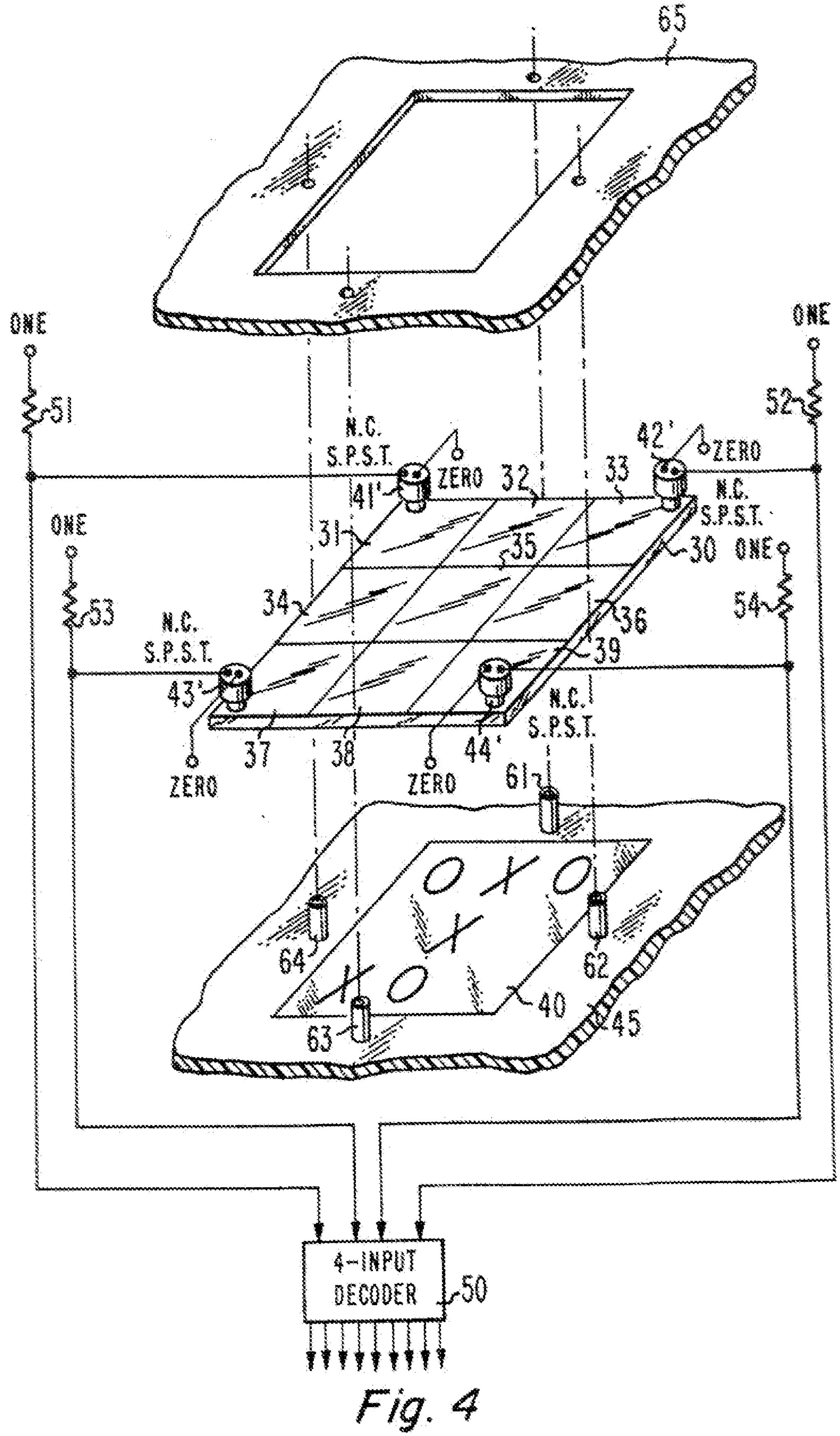
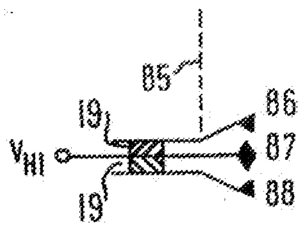

65
ONE
51
ONE
52
N.C.
S.P.S.T.
41'
ZERO
32
33
42'
ZERO
N.C.
S.P.S.T.
31
35
30
ONE
ONE
53
34
36
54
N.C.
S.P.S.T.
39
43'
37
38
44'
N.C.
S.P.S.T.
ZERO
ZERO
61
64
62
63
40
45
4-INPUT
DECODER
50

Fig. 4



DETAIL OF SWITCHES
81 82 83 84

Fig. 5a.

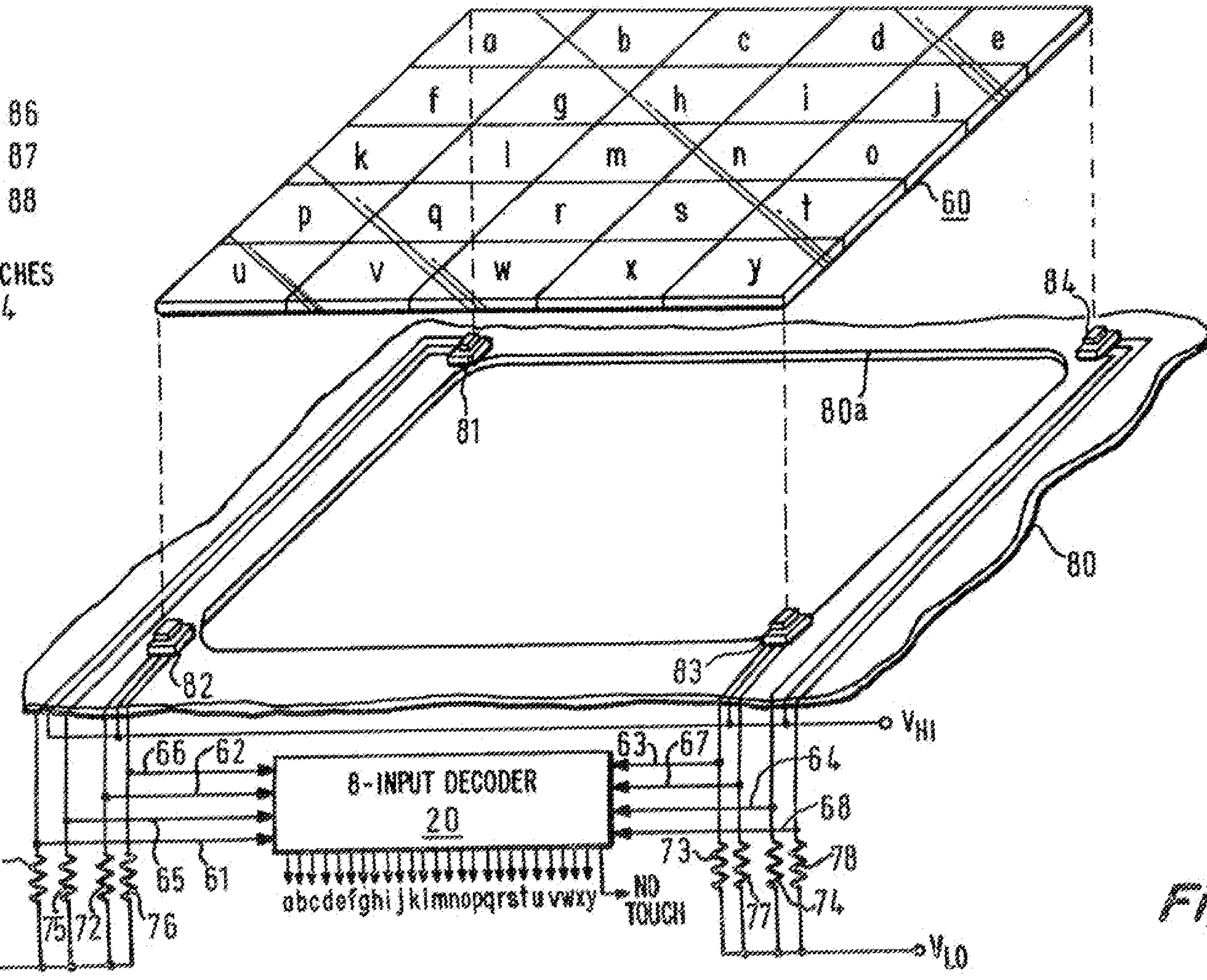


Fig. 5.

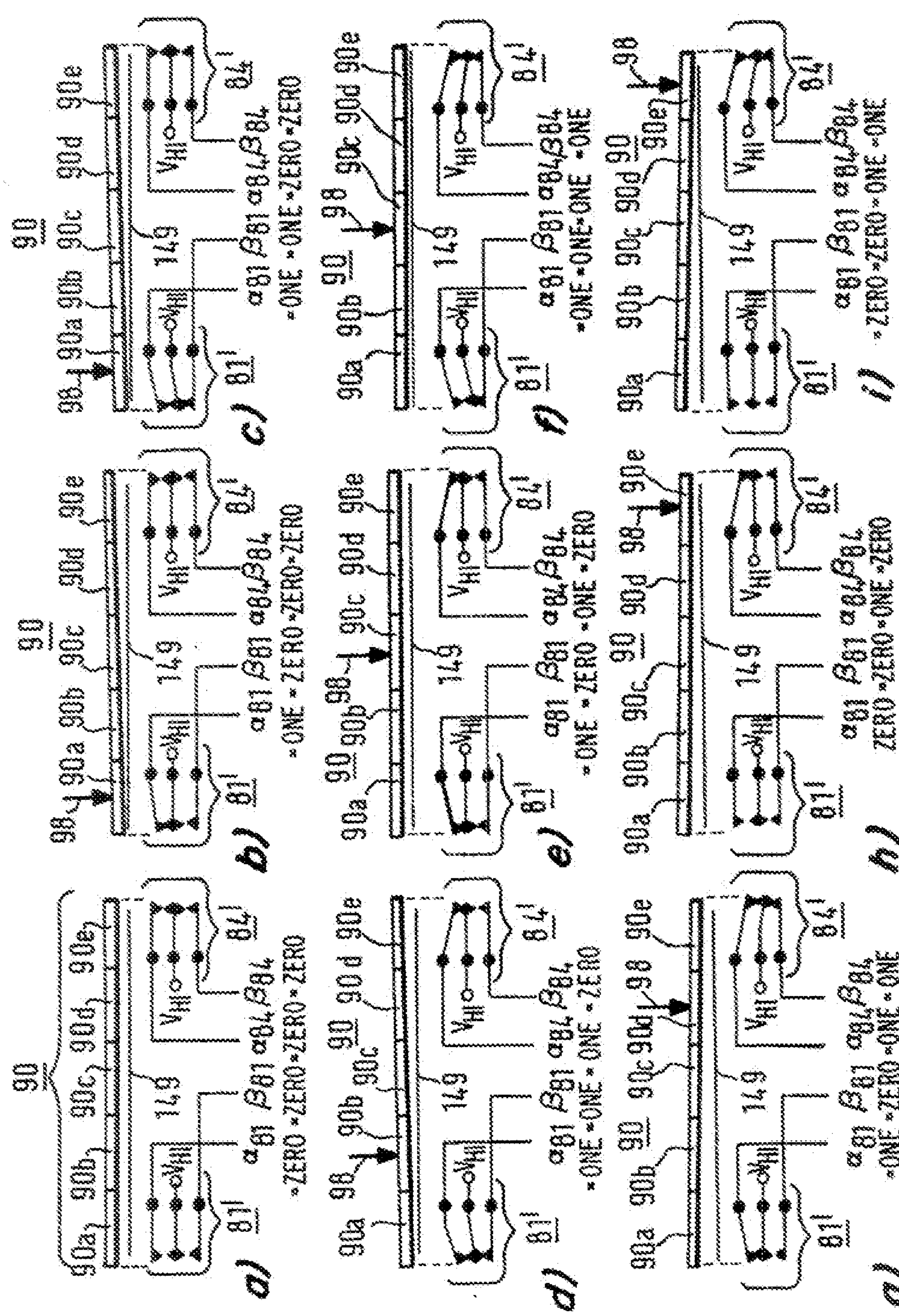


Fig. 6.

2126388

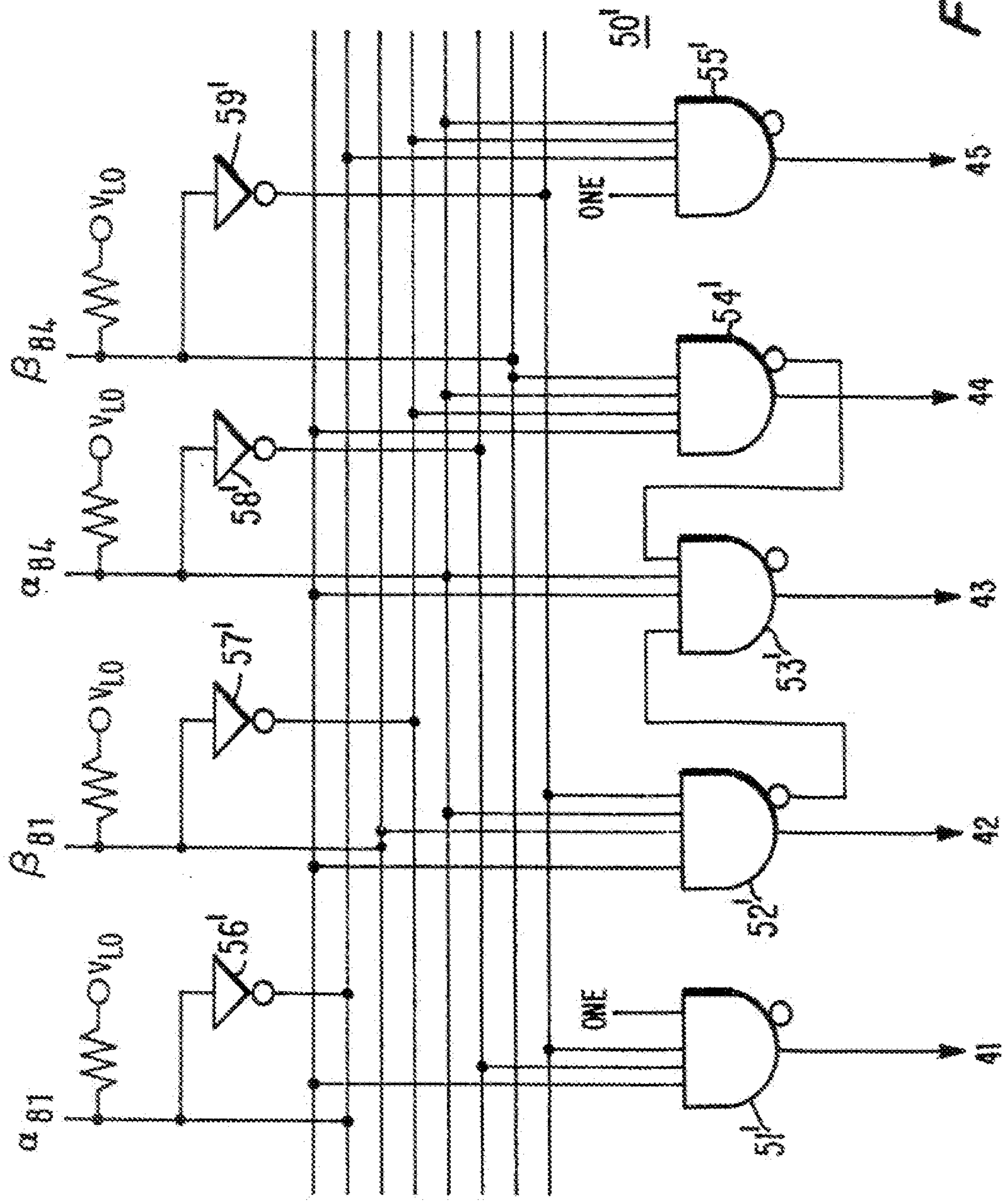


Fig. 7.

Fig. 8a

TABLE III

REGION BEING TOUCHED	SWITCH 81		SWITCH 82		SWITCH 83		SWITCH 84	
	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS
a	1 1	0 1	0 0	0 0	0 0	0 0	0 0	0 0
b	1	1	0	0	0	0	1	0
c	1 1	0 1	0 0	0 0	0 0	0 0	1 1	0 1
d	1	0	0	0	0	0	1	1
e	0 0	0 0	0 0	0 0	0 0	0 0	1 1	0 1
f	1	1	1	0	0	0	0	0
g	1	1	1	0	0	0	1	0
h	1	1	1	0	1	0	1	1
i	1	0	0	0	1	0	1	1
j	0	0	0	0	1	0	1	1
k	1 1	0 1	1 1	0 1	0 0	0 0	0 0	0 0

Fig. 8b

TABLE III CONT.

REGION BEING TOUCHED	SWITCH 81		SWITCH 82		SWITCH 83		SWITCH 84	
	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS
l	1	1	1	1	1	0	1	0
m	1 1	0 1	1 1	0 1	1 1	0 1	1 1	0 1
n	1	0	1	0	1	1	1	0
o	0 0	0 0	0 0	0 0	1 1	0 1	1 1	0 1
p	1	0	1	1	0	0	0	0
q	1	0	1	1	1	0	0	0
r	1	0	1	1	1	1	1	0
s	0	0	1	0	1	1	1	0
t	0	0	0	0	1	1	1	0
u	0 0	0 0	1 1	0 1	0 0	0 0	0 0	0 0
v	0	0	1	1	1	0	0	0

Fig. 8c

TABLE III CONT.

REGION BEING TOUCHED	SWITCH 81		SWITCH 82		SWITCH 83		SWITCH 84	
	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS
w	0 0	0 0	1 1	0 1	1 1	0 1	0 0	0 0
x	0	0	1	0	1	1	0	0
y	0 0	0 0	0 0	0 0	1 1	0 1	0 0	0 0

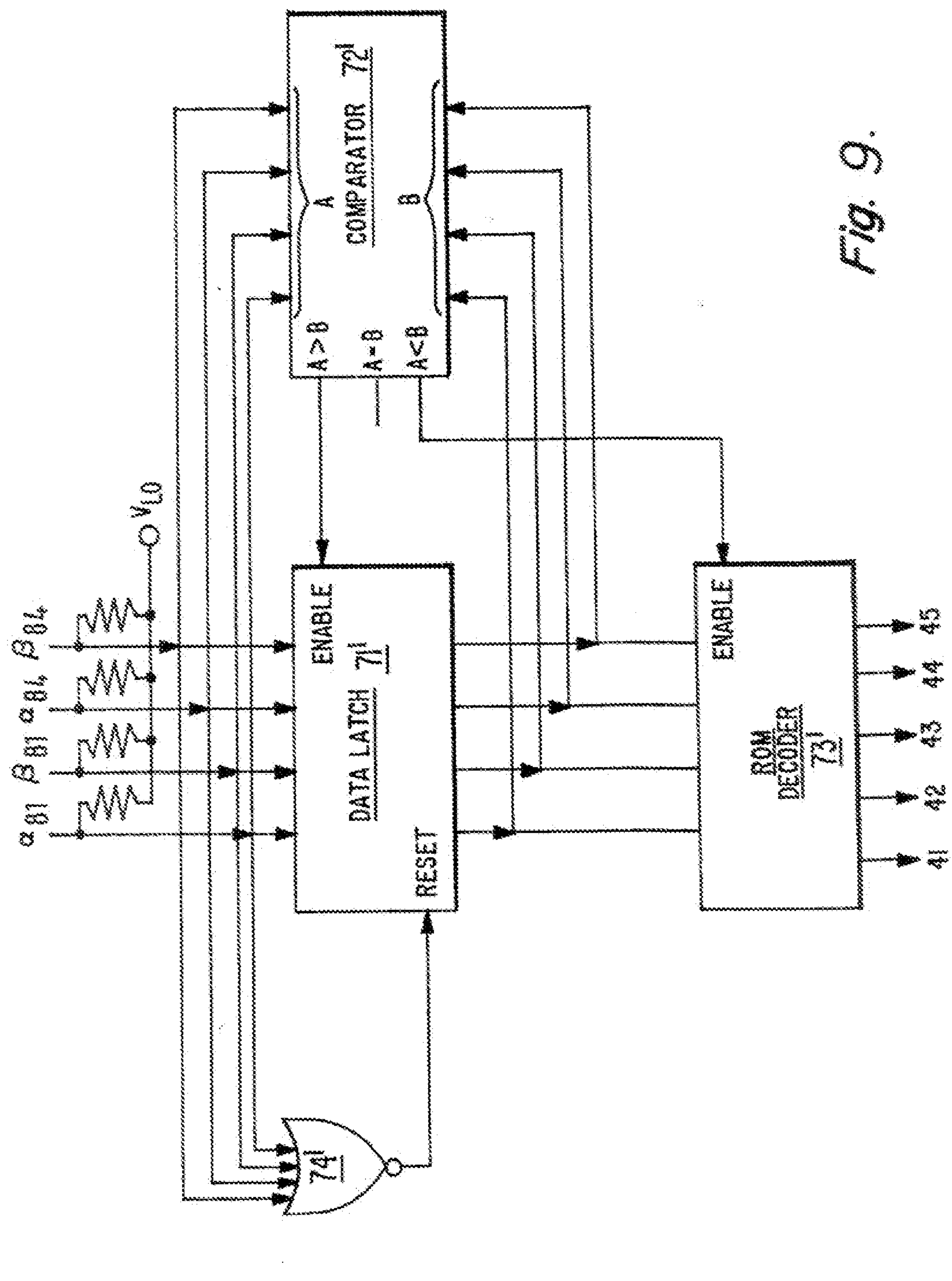

COMPARATOR 72'
A
B
A > B
A = B
A < B
DATA LATCH 71'
ENABLE
RESET
ROM DECODER 73'
ENABLE
74'
V_{LO}
α_{B1}
β_{B1}
α_{B4}
β_{B4}
41
42
43
44
45

Fig. 9.

SPECIFICATION

Touch responsive apparatus

The present invention relates to touch-responsive apparatus.

In certain electronic games apparatus or in computer-user interface apparatus, a member, which is referred to hereinafter as a touchbar or a touchplate, is included in the apparatus. A viewer-user of the apparatus communicates with such a game or computer by applying force to any selective one of a multiplicity of valid touch areas (also referred to hereinafter as touch points) on a surface of the touchbar or touchplate. The touchbar or touchplace may be transparent and lie over for example a viewscreen of a kinescope, another light-emitting-device display or a liquid-crystal display. To be useful, such apparatus must be simple in the mechanical sense, in order to assure both low cost and dependability.

The touch-responsive apparatus of the invention includes a member (for example, a touchbar or touchplate) having on a surface thereof a multiplicity of the valid touch areas; and a structure for supporting said member, and according to the invention, the member has a plurality of support points, which are fewer in number than the number of valid touch areas; a like-numbered plurality of force-sensitive switch means extend between respective support points and the supporting structure; each force-sensitive switch means (a) is biased to a normal condition (for example, in the absence of a applied force which is less than a predetermined level) and (b) is responsive to a force (in the example, equal to or greater than the threshold level) between the support structure and a respective member support point by assuming to at least one operated condition, where such forces are caused by applying actuating forces to ones of said member touch areas; and a decoder responds to combinations of operated conditions of the switch means to identify any one of said touch areas to which actuating force is applied.

In the drawing:

Figure 1 is a sketch of four possible conditions encountered in an illustrative touchbar apparatus embodying the present invention and using normally-open switches;

Figure 2 is a sketch of an illustrative touchbar apparatus embodying the present invention and using normally-closed switches;

Figure 3 is an exploded view of an illustrative touchplate apparatus embodying the present invention and using normally-open switches; and

Figure 4 is an exploded view of an illustrative touchplate apparatus embodying the present invention and using normally-closed switches.

Figure 5 is an exploded view of an illustrative assembly constructed in accordance with the invention, with *Figure 5A* providing an electrical schematic of the plural-closure switches used in the Figure 5 assembly;

Figure 6a-i diagram force conditions on an illustrative touchbar or on a touchplate assembly in accordance with the invention, which is shown in profile and is supported by force-discriminating double-closure force-sensitive switches;

Figure 7 is a schematic diagram of a typical four-input decoder arrangement for use with a touchbar per Figure 6;

Figures 8a, 8b, and *8c* are a table descriptive of the operation of a decoder used with the Figure 5 touchplate assembly; and

Figure 9 is a schematic diagram of circuitry for selecting most probably correct decoder output in determining touchpoint location.

Figures 1(a), 1(b), 1(c) and 1(d) show in profile a rigid, elongated touchbar 10 divided along its length into linearly arrayed touch areas, namely: a left section 11, a middle section 12 and a right section 13. Touchbar 10 is supported at its left end by a normally-open single-pole-single-throw push-button switch 15. The valid touch points thus are arrayed linearly between support points, which are at the ends of touchbar 10. The number (two) of support points is fewer than the number (three) of valid touch points.

Touchbar 10 is made of transparent material, such as a clear plastic and a support structure including mounting plate 5 (shown in cross-section) is provided. Switches 14 and 15 are mounted on plate 5, which has a hole in it between the switches, so an underlying screen 7 (shown in profile), may be viewed through the touchplate and the hole. Alternatively, screen 7 may be on top of plate 5 and the hole in plate 5, omitted. It is convenient to use printed-circuit (p-c) switches for switches 14 and 15 and to make plate 5 the printed circuit board for receiving them. A high level voltage (V_{HI}) or logic ONE level is provided to one terminal of switches 14 and 15.

Switch 14, when closed in response to user-applied downward force 8 on touchbar 10, applies the high level voltage V_{HI} to interconnection bus 16 to lift the bus voltage from logic ZERO to logic ONE condition. Switch 15, when closed in response to user-applied downward force 8 on touchbar 10, applies the high level voltage V_{HI} to interconnection bus 17 to lift the bus voltage from logic ZERO to logic ONE condition. Resistances 18 and 19 connect busses 16 and 17 to a low level voltage V_{LO} to pull down the bus voltages to logic ZERO when logic ONE is not applied from a comparatively low source resistance by closure of switch 14 or 15. The push buttons of switches 14 and 15 can be joined by a flexible cement to touchplate 10 at the points they are to support. Providing switches 14 and 14 have sufficient side-play in their closing action, the cement need not be flexible. A two-input decoder 20 – comprising AND gates 21, 22, and 23 and logic inverters 24 and 25, for example – supplies output lines corresponding to sections 11, 12, and 13. A logic

ONE appears on the one of these lines corresponding to the one of the sections 11, 12 and 13 to which a user applies sufficiently large downward force.

In Figure 1(a) touchbar 10 does not have applied to it any downward force sufficiently large to close either switch 14 or switch 15. Busses 16 and 17 are both at logic ZERO. AND gates 21, 22, and 23 all have at least one ZERO input from these busses. So the output signals of each of these gates is a ZERO.

In Figure 1(b) the left section 11 of touchbar 10 has sufficient downward force 8 applied on it by a user to close normally-open push-button switch 14. When further rotation of touchbar 10 is restrained, there must be equality between the clockwise and counterclockwise first moments around the point of application of force by the user, so the respective upward forces exerted by push-button switches 14 and 15 to oppose user-applied downward force 8 have to be in inverse proportion to their distance from the point of application of that downward force. The substantially shorter distance of switch 14 from point of application of downward force resolves most of that force for application to its push-button and provides for closure of switch 14, while leaving switch 15 open. Bus 16 has a ONE applied to it, while bus 17 remains at ZERO. This ZERO is inverted to ONE by inverter 24 and the resultant ONE is applied to one of the inputs of AND gate 21, the other of which receives a ONE from bus 16. The output of AND gate 21 goes to ONE responsive to both its inputs being ONEs and indicates user-applied force 8 being applied on the left section 11 of touchbar 10.

AND gate 22 supplies an output ZERO responsive to ONE input from bus 16 and ZERO input from bus 17. Inverter 25 inverts the ONE on bus 16 to apply a ZERO as input to AND gate 23, as well as it receiving an input ZERO from bus 17. AND gate 23 responds with an output ZERO.

In Figure 1(c) the right section 13 of touchbar 10 has sufficient downward force 8 applied on it by a user to close normally-open push-button switch 15. Operation analogous to that described with respect to Figure 1(b) results in AND gates 21 and 22 having ZERO output signals and in AND gate 23 having a ONE output signal.

Figure 1(d) shows the touchplate 10 receiving applied downward force 8 in its middle section 12. This force is resolved equally into forces on each of the normally-open push-button switches 14 and 15, closing them to apply ONEs to both the busses 16 and 17. AND gates 21 and 23 receive input ONEs directly from respective ones of busses 16 and 17, and these AND gates receive input ZEROs from the outputs of inverters 24 and 25 responsive to the input ONEs they receive from respective ones of the busses 16 and 17. AND gates 21 and 23 respond to these inputs with output ZEROs, while AND gate 22 responds with output ONE to input ONEs received from busses 16 and 17.

Figure 2 shows how the touchbar 10 may be mounted to use normally-closed single-pole-single-throw push-button switches 14′ and 15′, rather than normally-open switches 14 and 15. The hole in mounting plate 5 permits the user to touch the top of touchplate 10 to open switch 14′ with sufficient force on left section 11, to open switch 15′ with sufficient force on right section 13, or to open both switches with sufficient force on middle section 12. Resistors 18 and 19 return busses 16 and 17 to a logic ONE supply voltage rather than a logic ZERO supply voltage, and the switches 14′ and 15′ in their normally closed positions short-circuit busses 16 and 17 respectively to a logic ZERO supply voltage.

The transparent touchbar arrangements of Figures 1 and 2 provide distinct responses to three touchpoint regions using only two push-button type switches. In the described arrangement, no switch impedes viewing a display screen through the touchbar.

In a touchplate arrangement, the member having touch points on its surface is rectangular (instead of elongated, as in the cases of the apparatus illustrated in Figures 1 and 2). As is brought out below in the description of Figure 3, the present invention also is used to identify touch points arranged on such a rectangular touchplate, where the touchpoints are disposed in rows and columns extending parallel to the touchplate surface. Using the invention in this context affords greater saving in the number of push-button switches per valid touch point then the above-discussed touch bar arrangement. As is brought out below, in the touchplate arrangement, four push-button switches and associated logic can be used to generate nine distinct responses to pressure on nine respective touchpoints arranged in an array of three rows and three columns. This type of transparent touchplate is useful in computer terminals for permitting the operator to select amongst nine alternatives presented to him by the computer on its graphic display cathode-ray-tube, for example. This type of transparent touchplate is useful, for example, as the user interface in an electronic tic-tac-toe game using an underlying liquid-crystal-display (LCD).

Figure 3 shows in exploded view how a rectangular transparent touchplate 30 with an array of valid touchpoints 31-39 thereon can be used to overlay a correspondingly rectangular screen 40 (e.g. that of an LCD for displaying tic-tac-toe circles and crosses). A plurality of four normally-open single-pole-single-throw push-button switches 41-44 support the corners of rectangular touchplate 30, their buttons being glued thereto with a flexible cement. Switches 41-44 are supported by a support member 45 surrounding screen 40. The valid touchpoints are arrayed in rows (e.g., a row including 31, 32, and 33) and columns (e.g., a column including 31, 34, and 37). The rows extend parallel to the length of plate 30 and the columns extend parallel to the width of plate 30. With this arrangement, the rows extend in directions parallel to lines extending between pairs of switches 41-47 and 43-44 which are located at pairs of corners defining the width of plate 30; and the columns extend in lines parallel to the pairs of switches (41-43 and 42-44) which are located at pairs of corners defining the length of plate 30.

In practice, it is easiest to use switches 41-44 designed for printed circuit boards and to use the printed circuit board as supporting member 45. The metalization on the p-c board is exposed as wiring in the

exploded view of Figure 3 for ease of illustration. When closed in response to user-applied force, switches 41, 42, 43 and 44 respectively clamp busses 46, 47, 48 and 49 to logic ONE voltage. Busses 46, 47, 48 and 49 supplying input signals to a four-input decoder 50 are otherwise held to logic ZERO voltage by resistances 51, 52, 53 and 54, respectively.

Decoder 50 is typically a four-input, 16-output decoder, nine of the outputs of which are usually used in touchplate apparatus embodying the invention. The CMOS-logic CD4514B manufactured by the Solid State Division of RCA Corporation at Somerville, NJ, is a suitable decoder of this type. The decoder is arranged to provide the nine outputs in accordance with the following truth table, no output indication being provided for the non-touch and non-valid conditions. In the table, the symbols "0" and "1" are used to designate that a referenced switch is open ("normal" condition) and closed (e.g., "operated" condition), respectively.

SWITCHES CLOSED				AREA TOUCHED
41	42	43	44	
0	0	0	0	NONE
0	0	0	1	39
0	0	1	0	37
0	0	1	1	38
0	1	0	0	33
0	1	0	1	36
0	1	1	0	NON-VALID
0	1	1	1	NON-VALID
1	0	0	0	31
1	0	0	1	NON-VALID
1	0	1	0	34
1	0	1	1	NON-VALID
1	1	0	0	32
1	1	0	1	NON-VALID
1	1	1	0	NON-VALID
1	1	1	1	35

The sixteen binary numbers established by the pattern of switch closure can be those enumerating the outputs of a sixteen-output, four-input decoder 50. The four outputs with three bit places being logic ONE are not normally used, nor are the two outputs with two bit places being logic ONE are generated by closure of diagonally opposite ones of switches, nor is the all ZERO output. These seven outputs may be OR'ed to generate feedback to the user, through aural, visual or tactile means that a valid selection of touchpoint has yet to be made.

Alternatively, the non-valid switch conditions (particularly those where three ONEs and a ZERO are generated) may be decoded and OR'ed with all-ONEs condition to indicate touching of the central touchpoint 35. The non-valid conditions never obtain, except on a transient basis, provided touchplate 10 is flat and rigid. Transparent plastic plates, particularly thinner ones, are subject to bending and warpage which may interfere with all four switches closing at once; if this is expected to occur, the alternative decoder algorithms are preferably to use.

Figure 4 shows the modification necessary to use normally-closed single-pole-single-throw push-button switches 41', 42', 43' and 44' instead of normally-open switches 41, 42, 43 and 44. Switches 41', 42', 43', and 44' have their backs mounted on a bezel plate 65 offset from support member 45 by means such as pins 61-64. The output is sufficiently large to accommodate switches 41'-44' and touchplate 10. Pins 61-64 may be drilled and tapped, and machine screws (not shown) may be threaded through corresponding holes in bezel plate 65 into the tapped holes to hold the plate in place. Or bezel plate 65 may be glued to the tops of pins 61-64.

Rather than using single-pole-single-throw push-button switches with pull-up or pull-down resistors to develop logic ZERO and logic ONE conditions, single-pole-double-throw push-button switches can be used to select between logic ZERO and logic ONE conditions.

Touchplates embodying the invention (e.g. as described in connection with Figure 4) may be arranged alongside touchbars embodying the invention (e.g. as described in connection with Figure 1) or other such touchbars to obtain three-column arrays of valid touchpoints which have more than three rows. The invention maybe useful in certain applications where the touchbar or touchplate is made of non-transparent material or is only transparent in part.

It will be appreciated that the above-described decoding functions may advantageously be performed in a microcomputer or other means than that shown. Steps may be taken in the microcomputer to suppress transient switch response conditions, by requiring that a touch be sustained for a predetermined time interval to be considered valid. Standard contact-debouncing circuitry may be used with decoder 20, for suppressing transient switch response conditions; for example, small capacitors can parallel resistors 18, 19

or 51, 52, 53, 54 to integrate switch response slightly.

Figure 5 shows an exploded view of a touchplate assembly having 25 valid touch areas. In certain respects, the construction of the Figure 5 assembly is similar to the assembly shown in Figure 3. Where each of switches 41, 42, 43 and 44 in Figure 3 has a single set of contacts which are open or closed, each of corresponding switches 81, 82, 83 and 84 in Figure 5 has two sets of normally open contacts, such as those indicated in Figure 5a. A first contact set (86, 87) is closed in response to application of a relatively small force to actuate member 85; and both the first contact set and a second contact set (87, 88) are closed in response to application of a relatively large force to 85. These sets of contacts are shown sharing a common contact 87 as indicated in Figure 5a. In the Figure 5a switch, light pressure on the push-button, or actuating member, 85 transmits a small force through it that bends leaf 86 to close the contacts 86-87 and 87-88. As used in the Figure 5 assembly such double-closure switches 81, 82, 83 and 84 are conveniently formed as printed circuit switches, allowing their mounting on a printed circuit board support member 80.

Support member 80 is shown as having a rectangular aperture 80A, having its corners close to the positions of switches 81, 82, 83, 84, in order to allow viewing of a screen (not shown) through transparent touchplate 60 and aperture 80A. As apparent from Figure 5, this screen is to be located below the hole in support member 80. Alternatively, support member 80 could be replaced by one of transparent material without a hole such as 80A and located below touchplate 60. Such a transparent support member could be provided an anti-reflective coating. In applications where there is no need to see through the touchplate, the touch plate and the support member can be opaque and without a hole therethrough.

Touchplate 60 is shown divided into a five-column-by-five-row array of valid touchpoint areas or locations. The locations are labeled with respective ones of the letters of the English alphabet excluding z. An eight-input decoder 70 responds to the busses 61, 62, 63, 64, 65, 66, 67 and 68 being selectively clamped to the voltage V_{HI}, which voltage can be associated with a logic ONE, by the closure of contacts in switches 81, 82, 83, and 84. Such closure would be in response to user-applied pressure on one of the touchpoints a-y of touchplate 60. Decoder 70 supplies an indication of a selected touchpoint (i.e., a touchpoint to which force is applied). This indication is supplied on one of twenty-five output lines, assuming decoder 70 output to be in non-coded form. When busses 61, 62, 63, 64, 65, 66, 67 and 68 are not clamped to V_{HI} by closure of contacts of switches 81, 82, 83 or 84, these busses are biased to voltage V_{LO}, the voltage associated with logic ZERO, via resistances 71, 72, 73, 74, 75, 76, 77 and 78, respectively.

The selective clamping process is considered, more particularly, switch by switch. When the first set of contacts close in switch 81 responsive to relatively light force on its push-button, bus 61 is clamped to the relatively high voltage V_{HI} associated with a logic ONE and applied on common to the sets of contacts in switch 81. When the first set of contacts close in switch 82 responsive to relatively small force on its push-button, bus 62 is clamped to the relatively high voltage V_{HI} associated with a logic ONE and applied in common to the sets of contacts in switch 82. When the first set of contacts close in switch 83 responsive to relatively small force on its push-button, bus 63 is clamped to the relatively high voltage V_{HI} associated with a logic ONE and applied in common to the sets of contacts in switch 83. When the first set of contacts close in switch 84 responsive to relatively small force on its push-button, bus 64 is clamped to the relatively high voltage V_{HI} associated with a logic ONE and applied in common to the sets of contacts in switch 84. When both sets of contacts in switch 81 close responsive to relatively large force on its push-button, both busses 61 and 65 are clamped to V_{HI}. When both sets of contacts in switch 82 close responsive to relatively large force on its push-button, both busses 62 and 66 are clamped to V_{HI}. When both sets of contacts in switch 83 close responsive to relatively largeforce on its push-button, both busses 63 and 67 are clamped to V_{HI}. When both sets of contacts in switch 84 close responsive to relatively large force on its push-button, both busses 64 and 68 are clamped to V_{HI}.

The patterns of closure of switches 81, 82, 83, 84 associated with pressure being applied to different ones of the touchpoints a-y on touchplate 60 will now be considered. This two-dimensional problem in resolving applied force into components at the support points is separable, and thus can be considered in terms of two orthogonal single-dimensional problems in resolving point of application, the first dimension being in the direction of rows in the rectangular array of touchpoints a-y and the second dimension in the direction of the columns in that array. This, in effect, reduces the problem of the rectangular touchplate supported at its corners to that of the linear touchbar supported at its ends.

Figures 6 a-i, show the various switch closure conditions that can obtain for a touchbar 90 divided from left to right along its length into five touchpoint regions 90a, 90b, 90c, 90d and 90e and supported at its ends by double-closure switches 81' and 84'. These various conditions result responsive to user-applied force (represented by vector 98) being applied on different ones of the regions 90a-90e. Analysis showing which switch contacts close is calculated according to the laws of classical mechanics, as applied to a beam support at each of its ends. After translation of the beam responsive to user-applied force 98 is completed, the applied force 98 (which may include a component ascribable to the touchbar or touchplate weight) is equal to the sum of the contervailing forces applied to the beam by the switches 81', 84' (and therefore to the forces applied to the switches by the beam). After rotational translation of the beam responsive to user-applied force is completed, clockwise first moments must equal counterclockwise first moments. The equations describing this equality about the point of application of force are then written and cross-solved with the previous equalities to resolve respective components of user-applied force at switches 81' and 84'. The component of user-applied force at each of the switches is then compared to the force thresholds (at

which one of its sets of contacts close and at which both of its sets of contacts close) to determine the conditions of each of the double-closure switches.

In the various portions of Figure 6, touchbar 90 or its like is presumed to be made of transparent material, permitting the viewing of a viewscreen 49, shown in profile, there under. Figure 6(a) illustrates the switch condition when no force is applied by the user to any of the touchpoints.

Figure 6b illustrates how relatively light force applied to the left end region 90a closes one set of contacts in switch 81′. Figure 6c illustrates how relatively strong force closes both sets of contacts in switch 81′. Both contact sets of switch 84′ remain open in both cases of Figures 6b and 6c.

Force applied to the middle region 90c will be resolved about equally between the actuating members of switches 81′ and 84′. Each switch will have one of its sets of contacts closed, if applied force is relatively light as in Figure 6e; or each will have both its sets of contacts closed if applied force is relatively strong as in Figure 6f.

Light force applied to the right-hand region 90e in Figure 6h closes one of contacts in switch 84′; and strong force applied to region 90e, as in Figure 2i, closes both sets in switch 84′. The contacts of switch 81′ remain open in either case.

Figure 6d shows the condition where force is applied to region 90b between left end region 90a and middle region 90c. The force is resolved into component forces on the actuating member of switches 81′ and 84′ that are relatively large and relatively small, respectively. Both sets of contacts in switch 81′ close, but only a single set in switch 84′.

Figure 6g shows the condition where force is applied to region 90d between middle region 90c and right end region 90e. The force is resolved into component forces on the actuating members of switches 81′ and 84′ that are relatively small and relatively large, respectively. Both sets of contacts in switch 84′ close, but only a single set in switch 81′ closes.

Figures 6(a-i) can be summarized into the following truth table. Each force-sensitive switch is considered to have a set of contacts, α, closed only for actuating forces greater than a relatively low threshold value and a set of contacts, β, closed only for actuating forces greater than a relatively high threshold value. Closure of contacts is signified by a logic ONE; and their opening, by a logic ZERO.

TABLE I

REGION BEING TOUCHED	LEFT SWITCH 81′		RIGHT SWITCH 84′	
	β CONTACTS	α CONTACTS	β CONTACTS	α CONTACTS
none	0	0	0	0
90e	0	0	0	1
impossible	0	0	1	0
90e	0	0	1	1
90a	0	1	0	0
90c	0	1	0	1
impossible	0	1	1	0
90d	0	1	1	1
impossible	1	0	0	0
impossible	1	0	0	1
impossible	1	0	1	0
impossible	1	0	1	1
90a	1	1	0	0
90b	1	1	0	1
impossible	1	1	1	0
90c	1	1	1	1

The impossible conditions in the table arise from letting the set of four-bit binary numbers describing contact conditions run consecutively to make sure no contact condition is omitted, while in actuality one cannot exert force on a double-closure switch above the threshold required to close its β contacts without closing its α contacts, which close at lower threshold. Table I maybe re-arranged to the more-convenient-to-use Table II following, with impossible conditions being omitted.

TABLE II

REGION BEING TOUCHED	LEFT SWITCH 81'		RIGHT SWITCH 84'	
	α CONTACTS	β CONTACTS	α CONTACTS	β CONTACTS
none	0	0	0	0
90a	1	0	0	0
	1	1	0	0
90b	1	1	1	0
90c	1	0	1	0
	1	1	1	1
90d	1	0	1	1
90e	0	0	1	0
	0	0	1	1

Where a simple five-touchpoint touchbar 90 is all that one requires, a simple four-input decoder is readily constructed to address five lines responsive to the contact conditions described in Table II as exemplified by decoder 50' in Figure 7. The design procedure for decoder 50' is to use an AND gate for each line of the table, and to apply inverted ("true") inputs to those gate inputs which are to receive logic ZERO and to apply non-inverted ("true") inputs to those gate inputs which are to receive logic ONE. The AND gate output is connected to the output line, both going to logic ONE whenever the specified associated touchpoint region is touched, if there is only a single line entry in the table for that region. If there are two lines in the table, then outputs of the AND gates for each entry are applied as inputs to an OR gate and its output is to the output line going to logic ONE whenever the associated touchpoint region is touched. Standard logic manipulation techniques can then be applied to the basic logic network.

Using Table II as a basis one can construct the truth table TABLE III beginning in Figure 8a and continued in Figures 8b and 8c to show the actuation of switches 81-84 in Figure 5 in response to application of force to touch areas a-y of plate 60. In resolving user force applied to any of the touchpoint areas a, b, c, d, e, u, v, w, x, y, (a) one of the rows (row a,b, c, d, e and row u, v, w, x, y) containing the touchpoint can be considered as a touchbar to which force is applied while (b) the other of the rows is considered to be a touchbar to which no force is applied. Similarly, in resolving user force applied to any of the touchpoint regions a, e, f, j, k, o, p, t, u, y, the column a, f, k, p, u and e, j, o, t, y can be considered as a pair of touchbars, the column only one of which receives actuating force. Such logic equations, which may be manipulated according to standard reduction techniques, are presented in a form that is suitable for implementation with twenty-five integrated circuit AND/NAND gates with eight-bit-wide inputs. An array of logic inverters or properly wired XOR gates is used to provide complemented input variables to those inputs of the AND/NAND gates requiring them. Alternatively, decoding could be performed by programmable read-only memories, by microporcessor or by a computer with which the touchplate is associated.

The logic equations defining the g, i, q, and s touchpoints can be made somewhat more complex to OR the conditions. In each of these cases, the switch in the corner nearest to the touchpoint has its high-force threshold exceeded, the switch in the corner furthest from the switch-point has only its low-force threshold exceeded, and the remaining switches have had similar force threshold conditions exceeded. This allows for larger than normal force on the touchpoint to be properly decoded. Where the touchplate is flexible, rather than rigid, the second conditions listed in Table III for a, e, u, and y touchpoints may be interpreted as response to light pressure on touchpoints g, i, q, and s instead.

Decoder 50', of the Figure 7 decoder, has decoded output which exhibits several different values when user force is applied to a touchpoint; this is also the case where the decoding function is carried out using a read-only memory, a microprocessor, or a computer. One can simply arrange to accept decoder output after waiting a time after force is applied, as detected by decoder output indicating at least one set of switch contacts being closed. Another way to select the most probably correct decoder output is to continuously sample the decoder output and select the decoder output associated with the most switch contacts being closed. Then, if this selected decoder output is not a valid output, the decoder output next before or next after in time is selected.

Figure 9 shows hardware for implementing such a decoder output selection scheme, as might be used after the Figures 6(a-i) touchbar 90. The extension to hardware for use in connection with the Figure 5 touchplate assembly and should be apparent to one skilled in the art.

Data latch 71' has been reset to all-ZEROs output at a time prior to the touchbar being touched. Latch 71 receives as input the α_{81}, β_{81}, α_{84}, and β_{84} logic variables from switches 81' ad 84' under touch bar 90 (in Figure 6). A comparator 72' compares the binary number defined by the variables α_{81}, β_{81}, α_{84} and β_{84} supplied as A-input to the binary number stored in latch 71' supplied as B-input. Greater force on the [illegible] and β_{84} either increasing or remaining the same,

never with its decrease, and there are no carriers in the binary number system used. So comparing the binary numbers compares the number of ONEs in them. When A-input exceeds B-input, comparator 72' supplies an enabling signal to latch 71' to latch in these higher α_{81}, β_{81}, α_{84}, and β_{84} variables.

When comparator 72 B-input exceeds A-input, the number stored in latch 71' describes the greatest force on the touchbar, so the A<B output is a validation signal indicating that decoding should proceed from the number stored in latch 71'.

A read-only memory (ROM) with input from latch 71' output is convenient to use as the decoder 73, with the validation signal being aplied to enable its reading.

When the force on the touchbar is discontinued, NOR gate 74' responds to α_{81}, β_{81}, α_{84}, and β_{84} all being ZERO to supply a ONE to reset latch 71' to all-ZEROs output.

The functions provided by the type of hardware just described can be realized using an appropriately programmed microprocessor. Where this is done accomodation can be made in the decoding decisions for the force a particular generator tends to exert, as determined from his validating a series of touchpoint selectors. Correlations of switch conditions as applied force changes can also be made to improve the accuracy of decoding decisions.

While in the embodiments of the invention shown in Figures 5 and 6, the decoding logic is such as to respond to switch closure patterns developed in response to both smaller and larger user-applied force on certain touchpoint regions, it is possible to use logic that responds to only one of these force conditions (e.g., the larger). While normally-open double-closure force-sensitive switches have been used between supporting surfaces and touchbars or touchplates pressed towards those supporting surfaces in the illustrated embodiments of the invention, embodiments of the invention may instead use normally-closed double-closure force-sensitive switches between supporting surfaces and touchbars or touchbars pressed away from those surfaces by touch applied through holes in those surfaces. Double-throw rather than single-throw switches may be used to eliminate the need for pull-up or pull-down resistors being used to establish alternative logic conditions when the switches are not user-actuated.

CLAIMS

1. A touch-responsive apparatus comprising: a member having a surface thereof which includes a multiplicity of valid touch areas and a structure for supporting said member;

wherein said member has a plurality of support points, which are fewer in number than the number of valid touch areas;

a like plurality of force-sensitive switch means, each switch means being biased to a normal condition and being responsive to a force between said structure and a respective member support point to at least one operated condition, where such forces are caused by applying actuating forces to selected ones of said member touch areas; and

a decoder responds to the operated conditions in combination of said switch means to identify any one of said touch areas to which actuating force is applied.

2. The apparatus of claim 1, wherein at least some of said touch areas are arrayed linearly between first and second of said support points.

3. The apparatus of claim 2, wherein said member is elongated; and

said support points are disposed adjacent opposite ends of said member.

4. The apparatus of claim 1, wherein said member is rectangular;

said touch areas are disposed within an array having rows and columns which extend parallel to the length of and width, respectively, of said rectangular member;

said support points are disposed adjacent respective corners of said rectangular member; and

said decoder responds to operation of any single one of said switch means, of each pair of switch means which are disposed adjacent ends of any side of said rectangular member, and of all said switch means, in accordance with the row and column in which the actuating force receiving one of said touch areas is located.

5. The apparatus of any one of claims 1 to 4, wherein said decoder is responsive to all said switch means being in normal condition for indicating that force is applied to none of the touch areas.

6. The apparatus of claim 3 or 4, wherein each of said switch means is of the plural closure type, and is operable to first operated condition and second operated conditions in response to the presence of a first force and a second, larger force, respectively, at a respective one of said support points;

and said decoder responds to certain combinations of normal condition and of first and second operated conditions among selected combinations of said switch means.

7. The apparatus of any one of claims 1 to 5 wherein each of said switch means comprises a pair of contacts which are open and closed when that one of said switch means is in normal condition and in operated condition, respectively.

8. The apparatus of any one of claims 1 to 5 wherein each of said switch means comprises a pair of contacts, which are closed and open, when that one of said switch means is in normal condition and operated condition, respectively.

9. The apparatus of any one of claims 1 to 8, for use with a viewscreen wherein said member is [illegible] screen when the screen is remote from said surface which

includes said valid touch areas.

10. Apparatus according to any preceding claim, further comprising means, responsive to the decoder, for providing to the user, an indication sensible by the user, that a valid touch area has been selected.

11. Touch responsive apparatus substantially as hereinbefore described with reference: to Figures 1a to 1d; or to Figure 2; or to Figure 3; or to Figure 4; or to Figures 5 and 5a optionally together with Figures 8a to c or with Figure 9; or to Figures 6a to i optionally together with Figure 7 or with Figure 9.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1984.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.